00-081

Embedding Data in Material

Background of the Invention

Field of the Invention

The present invention relates to embedding data in material.

"Material" as used herein means information material represented by information signals which includes at least one or more of image material, audio material. Image material is generic to still and moving images.

Description of the Prior Art

Steganography

Steganography is the embedding of data into material such as video material, audio material and data material in such a way that the data is imperceptible in the material.

Data may be embedded as a watermark in material such as video material, audio material and data material. A watermark may be imperceptible or perceptible in the material.

A watermark may be used for various purposes. It is known to use watermarks for the purpose of protecting the material against, or trace, infringement of the intellectual property rights of the owner(s) of the material. For example a watermark may identify the owner of the material.

Watermarks may be "robust" in that they are difficult to remove from the material. Robust watermarks are useful to trace the provenance of material which is processed in some way either in an attempt to remove the mark or to effect legitimate processing such as video editing or compression for storage and/or transmission. Watermarks may be "fragile" in that they are easily damaged by processing which is useful to detect attempts to remove the mark or process the material.

Visible watermarks are useful to allow e.g. a customer to view an image e,g. over the Internet to determine whether they wish to buy it but without allowing the customer access to the unmarked image they would buy. The watermark degrades the image and the mark is preferably not removable by the customer. Visible watermarks

are also used to determine the provenance of the material into which they are embedded.

It is known to embed data in material. It is desirable to do that and allow the data to be removed from the material to avoid degrading the material. It is desirable to minimise any charges to the material needed to embed the data in it to avoid degrading the material. It is known to combine the data with the material, the data being scaled by a scaling factor which is chosen according to desired properties of the data when combined with the material. Those properties include one or more of: concealing the data in the material; making the data perceptible in the material; making the data, when embedded in the material, resistant to processing which, intentionally and unintentionally, removes or damages the embedded data.

SUMMARY OF THE INVENTION

According to a first aspect of the invention, there is provided a method of embedding data in material, the method comprising

combining a representation of the material with a function of the data and a scaling factor; wherein

the scaling factor is generated as a function of a trial decoding of the material, the trial decoding comprising processing the material to recover data therefrom.

Thus the scaling factor can be chosen on the basis of an estimate of the result of a process (e.g. decoding) which will be performed on the combined material and data in practice so as to increase the likelihood that the data is recoverable from the material.

An embodiment of the first aspect of the invention further comprises the steps of:

combining, as a trial, a representation of the material with a function of the data and a trial scaling factor; and

performing, as a trial, a predetermined process on the combined material and data;

wherein the scaling factor is generated as a function of a trial decoding of the processed combined material and data.

Thus the scaling factor can be chosen on the basis of an estimate of the result of a process (e.g. JPEG processing) which could be performed on the combined

material and data in practice and which may damage the embedded data, so as to increase the likelihood that the data will not be damaged by such processing .

According to the first aspect of the invention, there is also provided a method of embedding data in material, the method comprising the steps of:

producing transform coefficients Ci representing a transform of the material;

producing a pseudo random symbol sequence (PRSS) having L symbols Pi of values +1 and -1;

calculating the correlation $S=\Sigma$ Ci.Pi, for i=1 to i=L; and

calculating modified coefficient values $Ci' = Ci + \alpha * Pi$, where α is calculated dependent on S and the value of the data bit to be embedded in the coefficient.

Preferably

$$\alpha = (\alpha' + \text{offset})$$

where α' + offset is a function of the data bit to be embedded in the coefficient, and the method comprises the step of calculating modified coefficient values

$$Ci' = Ci + (\alpha' + \text{offset})*Pi \text{ where}$$

α' =0 if S is positive and the data to be concealed is a bit of a first value,

α' =0 if S is negative and the data to be concealed is a bit of a second value,

and otherwise α' is a function of S such that Σ Ci'.Pi has the correct sign to represent the bit to be encoded.

It will be noted that the calculation of the correlation $S=\Sigma$ Ci.Pi, for i=1 to i=L is a form of trial decoding as in the said first aspect and the scaling factor is chosen in dependence on that correlation.

A further aspect of the invention provides a computer program product arranged to carry out one of the aforesaid methods when run on a computer.

The invention also provides corresponding apparatus in other aspects of the invention.

According to a second aspect of the present invention, there is provided a method of embedding data in material, comprising the steps of:

producing transform coefficients Ci of the material;

comparing the magnitudes of the coefficients with a threshold value T; and

producing, from the coefficients Ci and the said data modified, coefficient values Ci' which are modified by respective information symbols of a pseudo random symbol sequence modulated by the said data to be embedded;

wherein the said step of producing modified coefficient values does not use coefficients of magnitude greater than the said threshold T and does not use the corresponding information symbols.

The data is detected at a decoder by correlating a pseudo random symbol sequence with the material in which the data is embedded. The data is represented by the sign of the correlation function. By not using, during embedding, coefficients which have a value greater than the threshold, any changes necessary to alter the coefficients to achieve the appropriate sign of the correlation value to represent a bit of the concealed data are minimised.

According to the second aspect of the present invention, there is also provided a method for detecting data embedded in material, the detecting method comprising

receiving transform coefficients of the material;

comparing the magnitudes of the received coefficients with a threshold value T; and

correlating, the said coefficients with a respective symbols of a pseudo random symbol sequence to detect the said data, wherein the correlating step does not use coefficients of magnitude greater than the said threshold T and corresponding symbols of the pseudo random symbol sequence.

Thus the detecting method is complementary to the embedding method.

The second aspect of the invention also provides the following a), and b):

a) Apparatus for embedding data in material comprising a transformer for producing transform coefficients Ci of the material;

a comparator for comparing the magnitudes of the coefficients with a threshold value T; and

a combiner for producing, from the coefficients Ci and the said data, modified coefficient values Ci' which are modified by respective information symbols of a pseudo random symbol sequence modulated by the said data to be embedded, wherein the combiner does not use coefficients of magnitude greater than the said threshold T and does not use the corresponding information symbols;

b) Apparatus for detecting data embedded in material comprising an input for receiving transform coefficients of the material;

a comparator for comparing the magnitudes of the received coefficients with a threshold T; and

a correlator for correlating, the said coefficients with respective symbols of a pseudo random symbol sequence to detect the said data, wherein the correlation does not use coefficients of magnitude greater than the said threshold T and the corresponding symbols of the pseudo random symbol sequence.

Yet further, according to the second aspect of the invention, there is provided a method of detecting data embedded in material, the method comprising;

receiving transform coefficients of the material;

comparing the magnitudes of the received coefficients with a threshold Tclip;

clipping, to a magnitude Tclip, the magnitude of coefficients of magnitude greater than the said threshold Tclip; and

correlating the clipped and unclipped coefficients with a pseudo random symbol sequence to detect data embedded in the material.

Yet further, apparatus according of the second aspect for detecting data embedded in material, comprises;

an input for receiving transform coefficients Ci' of the material;

a comparator for comparing the magnitudes of the received coefficients with a threshold Tclip;

means for clipping, to a magnitude Tclip, the magnitude of coefficients of magnitude greater than the said threshold Tclip; and

a correlator for correlating the clipped and unclipped coefficients with a pseudo random symbol sequence to detect data embedded in the material.

This further aspect of the invention may involve only the detecting method and operates independently of the embedding method. By clipping large value coefficients to a preset smaller value, such coefficients no longer dominate the value of the correlation function needed to decode the embedded data.

However, preferably, there is provided:

a) A method of embedding data in material, the method comprising

receiving transform coefficients Ci representing the material;

comparing the magnitudes of the said transform coefficients Ci with a threshold Tclip;

clipping, to the magnitude Tclip, the magnitudes of those of the coefficients having a magnitude exceeding Tclip to produce clipped coefficients; and

producing modified coefficients Ci' of values dependent on a scaling factor and the data to be embedded, and the scaling factor is calculated using the said clipped coefficients and the coefficients Ci of magnitude less than Tclip.

b) Apparatus for embedding data in material, the apparatus comprising:

an input for receiving transform coefficients Ci representing the material;

a comparator for comparing the magnitudes of the said transform coefficients with a threshold Tclip;

a clipper for clipping, to the magnitude Tclip, the magnitudes of those of the coefficients having a magnitude exceeding Tclip; and

a processor for producing modified coefficients Ci' of values dependent on a scaling factor and the data to be embedded, and the scaling factor is calculated using the said clipped coefficients and the coefficients Ci of magnitude less than Tclip.

Thus by clipping large value coefficients to a smaller value such coefficients no longer dominate the value of the function used to calculate the scaling factor.

The invention also provides a computer program product arranged to carry out one of the aforesaid methods when run on a computer.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the invention will be apparent from the following detailed description of illustrative embodiments which is to be read in connection with the accompanying drawings, in which:

Figure 1 is a schematic block diagram of an embodiment of a watermarking system according to the present invention;

Figure 2 is a schematic block diagram of another embodiment of a watermarking system according to the present invention;

Figure 3A is a schematic diagram of a wavelet transform showing the relationship of the symbols of a pseudo random symbol sequence to coefficients ;

Figure 3B is a flow diagram of calculations performed by the system of Figure 2;

Figure 4 is a schematic block diagram of an illustrative watermark decoding and removal system;

Figure 5 is a flow diagram of calculations performed by the watermark remover and decoder of Figure 4;

Figure 6 is a schematic block diagram of a further embodiment of a watermarking system according to the present invention;

Figures 7 to 10A are schematic block diagram of subsystems of the system of Figure 6;

Figures 10B and 10C are flow diagrams illustrating a process for calculating α;

Figure 11A is a flow diagram of a modification, in accordance with the invention, of the flow diagram of Figure 3B;

Figure 11B is a diagram showing the relationship of coefficients C_i and symbols P_i of a pseudo random symbol sequence;

Figure 12 is a flow diagram of a modification, in accordance with the invention, of the flow diagram of Figure 5;

Figure 13 is a flow diagram of another modification, in accordance with the invention, of the flow diagram of Figure 5;

Figures 14 and 15 are diagrams explaining wavelet transforms; and

Figures 16 and 17 are diagrams showing a UMID and a data reduced UMID.

Description of the Preferred Embodiments

Overview

Referring to Figure 1, in the shown illustrative watermarking system, a spatial domain image I produced by a source 1 is combined with watermark data Ri to produce a spatial domain watermarked image I'. The watermarked image is produced by an embedder 3 according to the equation

$$Ci' = Ci + \alpha.\ Ri$$

where Ci and Ci' are, for example, wavelet transform coefficients of the image, and α is a parameter which is also referred to herein as a scaling factor. α is chosen in this example so that the watermark is imperceptible in the image and to resist removal of the watermark by unauthorised processing. It is thus desirable that α has the

smallest value which achieves that. If α is too big the watermark is perceptible in the image; if it is too small the mark may not survive processing of the image.

In accordance with this embodiment, α is determined from a trial decoding of the original *unmarked* image I in a decoder 4. The decoding is that which would be used to decode the watermarked image I'. A value α' is produced by a calculator S3-S8, to which an offset value is added by an adder S9 to produce α. This produces values of α over the image, which are used to scale the data Ri so as to conceal the data.

Figure 2 shows an example of the system of Figure 1 in which the calculation of α also encodes Ri. Figure 6 shows an example of the system of Figure 1 in which the trial decoding takes place after a trial processing of the image data by a process which is likely to be applied to the watermarked image.

The data Ri in the examples given below is derived from a UMID. UMIDs are described in the section *UMIDs* below. As mentioned above, and in the examples given below, the image is subjected to a wavelet transform. Wavelet transforms are briefly discussed in the section *Wavelets* below.

Figure 2

Referring to Figure 2, for the purposes of explanation, it is assumed that the wavelet transform applied to the original spatial domain image results in a transform having four sub-bands of level 1: see the section *Wavelets* below. For ease of explanation the following description will refer only to the upper horizontal sub-band, but it will be appreciated that the present invention can be applied to any sub-band and may be applied to a plurality of sub-bands. The coefficients of the wavelet transform are denoted by Ci where i is the i^{th} coefficient of a sequence of JxL coefficients where there are J bits of UMID data W1 to WJ. As will become apparent the JxL coefficients correspond to symbols Pi of a Pseudo Random Symbol Sequence PRSS. Each UMID bit is embedded in L wavelet coefficients. Watermark data bit W_j is embedded in coefficients C_i for i = (j-i)L+1 to jL.

In this example a UMID is produced as the watermark data by a UMID generator 6. In this example the watermark is imperceptible. The data of the UMID is combined with the wavelet coefficients Ci in an embedder 3 in the manner described

in detail in the following text. The transformed image together with the watermark Ci' is subjected to an inverse wavelet transform T^{-1}, (5) to produce a spatial domain watermarked image I'.

The watermark is decoded and, optionally, removed from the watermarked image using the illustrative decoding and removal system of Figure 4.

Trial decoder 4

A trial decoder 4 comprises a generator 4_1, a converter 4_2, and a correlator S1. The generator 4_1 produces a pseudo random symbol sequence (PRSS) which is pseudo random because the sequence whilst appearing random can be reliably reproduced. The binary sequence has a length of JxL bits. The converter 4_2 converts the binary 1 and 0 to +1 and -1 respectively to produce a pseudo random symbol sequence (PRSS) Pi of values +1 and -1. The symbols of the PRSS are denoted herein by Pi, where i denotes the i^{th} symbol of the sequence which is JxL symbols long. The correlator SI produces correlation values

$Sj = \Sigma Ci.Pi$, where the sum is taken over the range $i = (j-1)L + 1$ to jL for each of $j=1$ to J. (See Figure 3A.)

Calculation of αj and embedding the UMID

There is one strength value αj for each UMID bit Wj.

The calculation of αj and the embedding of the UMID in the image operates in accordance with the flow diagram of Figure 3B. The embedder 3 calculates a function

$Ci' = Ci + \alpha j\, Pi$ for $i = (j-1)L + 1$ to jL for each of $j=1$ to J.

where Ci' is an ith wavelet coefficient modified to encoded a bit of watermarking data; and

αj is the scaling factor, the value of which depends on:

a) the value 1 or 0 of a bit Wj of the UMID to be encoded in modified coefficient Ci'; and

b) the sign of the correlation value $Sj = \Sigma Ci.Pi$, for $i = (j-1)L + 1$ to jL for each of $j=1$ to J, produced by the trial decoder 4; and

c) the offset value, which is +/-1 in this example, so $\alpha j = \alpha j' + \text{offset}j$.

The principle of operation is that a watermark bit $Wj=1$ is encoded as a positive correlation value and $Wj=0$ is encoded as a negative correlation value (or vice versa). αj is chosen to ensure the value of a correlation $Sj' = \Sigma Ci'.Pi$ for $i = (j-1)L + 1$ to jL for each of $j=1$ to J, performed *at the decoder* has the correct sign to represent the value of bit Wj. If the correlation Sj performed at the encoder has the correct sign, then $\alpha j' = 0$ otherwise $\alpha j'$ is modified to ensure that the correlation $Sj' = \Sigma Ci'.Pi$ performed at the decoder has the correct sign.

Thus referring to Figure 3B:-

A value $\alpha j'=\alpha j-$ offsetj.

Step S1 (correlator S1 of Figure 2) calculates the correlation value $Sj = \Sigma Ci.Pi$, where the sum is taken over the range $i = (j-1)L + 1$ to jL for a sequence $i = (j-1)L + 1$ to jL of coefficients Ci and PRSS bits Pi. (Note that 'symbols' Pi have values +1 and -1 to ensure that bits of value 0 produced by the generator 4_1 contribute to the value of Sj.) Step S1 is a trial decoding with a trial value of $\alpha j = 0$.

Step S2 determines whether the bit Wj of the UMID generated by generator 6 is 1 or 0. It will be appreciated that the bit Wj is in effect encoded over L coefficients. If $Wj =1$ then steps S3 to S5 and $S9^+$ are followed. These steps are implemented by blocks S3-S8 and S9 in figure 2.

Step S3 determines the sign of the correlation Sj. If the sign is positive and the bit Wj is 1 then

at step S4 $\alpha j' =0$.

If the sign determined at step S3 is negative but the bit $Wj =1$ (which should be encoded by Sj positive), then

at step S5 $\alpha j'=-Sj/(L-1)$.

At step $S9^+$, the offset +1 is added to ensure that αj is positive if $Sj=0$ and to increase robustness.. It should be noted that the offset is a signed value (+1) in this example.

If $Wj=0$ then steps S6 to S8 and $S9^-$ are followed. These steps are implemented by blocks S3-S8 and S9 in figure 2.

Step S6 determines the sign of the correlation Sj. If the sign is negative and the bit Wj is 0 then

at step S7 $\alpha j' = 0$.

If the sign determined at step S6 is positive but the bit $Wj = 0$ (which should be encoded by S negative), then

at step S8 $\alpha j' = -Sj/(L-1)$.

At step S9' the offset -1 is added to ensure that αj is negative if $Sj=0$ and to increase robustness. It should be noted that the offset is a signal value (-1) in this example.

At step S10 the value $Ci' = Ci + \alpha j\, Pi$ is calculated for $i = (j-1)L + 1$ to jL.

The value $\alpha j' = -Sj/(L-1)$ is an example. The value $\alpha j'$ could be $\alpha j' = -Sj/L$ as another example.

At step S9' an offset of +1 could be subtracted from $\alpha j'$.

<u>Watermark Decoding and Removing System (Figures 4 and 5)</u>

Referring to Figure 4, the watermark removing and decoding system has an input for receiving a spatial domain watermarked image I' from the system of Figure 1. The image may have been subject to image processing (not shown) between production by the system of Figure 1 and the receipt by the system of Figure 4.

The received image is transformed by a wavelet transformer 46 (T) to produce wavelet coefficients Ci'. The coefficients Ci' are provided to a synchroniser 8 which correlates the coefficients with a PRSS generated by a generator 10. The synchroniser 8 and the PRSS generator 10 carry out, in known manner, correlations with differing shifts of the PRSS relative to the coefficients to determine the position in the watermarked transformed image of the original PRSS produced at the watermarking system of Figure 1. Once synchronisation has been achieved the coefficients Ci' are correlated with the PRSS in another correlator 12 to produce the correlation value

$Sj' = \Sigma Ci'.Pi$ for $i = (j-1)L + 1$ to jL for each of $j=1$ to J.

where Pi has values +1 and -1.

The correlation value Sj' is provided to a decoder 14 and to a remover 16, the operations of which will be described with reference to the flow diagram of Figure 5. The decoder 14 extracts the UMID from the image. The watermark is removed by the

remover 16. The resulting restored transformed image is subject to an inverse wavelet transform (T^{-1}) in an inverse transformer 18.

Referring to Figure 5, the synchronisation of the PRSS with the received transformed image occurs at step S12. At step S14, the correlation value

$Sj' = \Sigma Ci'.Pi$ for $i = (j-1)L + 1$ to jL.

is calculated over a length L of the PRSS.

At step S16, the sign of the value Sj' is determined. If Sj' is negative then the bit of the watermark, (the UMID in this example), is 0. If Sj' is positive the bit of the watermark is 1.

At step S18,

$$\alpha j = Sj'/(L-1)$$

is calculated from Sj'. (This calculation may be an approximation because it assumes that $\Sigma Ci.Pi = 0$)

At step S22, $Ci = Ci' - \alpha j\ Pi$ is calculated for . $i = (j-1)L + 1$ to jL.

If, in the embedding process, αj is calculated as $-\frac{Sj}{L}$ at the step S5 or S8, then in the decoding process $\alpha j'$ is calculated as Sj'/L at step S18.

Modifications.

a). Threshold on the values of Ci and Ci^i (Figure 11A, Figure 12)

In a modification of the embodiment described above, the values of the coefficients Ci are compared (S40) with a threshold value Th_e at the embedder of Figure 2, and the values of the coefficients Ci' are compared S41 with a threshold value Th_d at the remover 16 of Figure 4 and also at the decoder 14 of Figure 4. If the value of a coefficient exceeds the threshold, that coefficient is not used (S42, S43) in establishing the correlation value Sj or Sj'. Th_e and Th_d may be equal, but it has been found that Th_d is preferably greater than Th_e.

By way of a simple example, assume that the PRSS has length L=4 and symbols P1 to P4 have values +1, -1,-1, and +1. Then referring to Table 1 three examples are shown.

	P1 C1	P2 C2	P3 C3	P4 C4	Sj, αj' Wj=0
Pi	+1	-1	-1	+1	
Ex1 Ci	-2	-5	+1	-3	-1, 0
Ex2 Ci	-2	-25	+1	-3	+19, -19/3
Ex3 Ci	-2		+1	-3	-6, 0

Table 1

Example 1 (Ex1)

The coefficients Ci have values shown. If the value of the bit Wj of the watermark to be encoded is 0 then according to Figure 3, Sj=-1 and so αj' =0.

Example 2 (Ex2)

However if as shown in example 2 the coefficient C2 has a value -25 than Sj=+19 and αj'=-19/3. Large values of αj' may cause the watermark to be perceptible when it should be imperceptible.

Example 3 (Ex3)

In accordance with an embodiment of the present invention, thresholds + Th_e and -Th_e - are set. The magnitude of Th_e may be about 6 for the above example. In practice it is set empirically. Thus as shown in Table 1, the coefficient C2 is not used in the calculation of Sj, and also the corresponding symbol of the PRBS is also not used. As a result Sj=-6 and αj'=0. Thus if the magnitude of a coefficient exceeds the threshold the coefficient is not used.

Now, referring to Figure 11A, in accordance with this embodiment, the following procedure takes place at the embedder before step S1 of Figure 3B.

At step S40, the magnitude of the coefficient value Ci is compared with the threshold Th_e. If the magnitude of Ci is greater than the threshold Th_e then at step S42 Ci is not used. Otherwise at step S44 Ci is used to calculate Ci' as described with reference to Figure 3B. Referring to Figure 11B, it will be recalled that each symbol Pi of the PRSS is associated with a coefficient Ci. When a coefficient Ci is not used because it exceeds the threshold, the corresponding symbol Pi generated by the generator 4 is also not used as indicated by the blocks Ci and Pi in Figure 11B.

b) Clipping coefficient values (Figure 13)

In an alternative modification, the values of the modified coefficients Ci' are clipped at the decoder of Figure 4 if they exceed (S80) a threshold value of magnitude Th_{clip}. Thus coefficient values greater than the threshold are reduced to a predetermined value e.g. Th_{clip}. For example referring to Table 1 Example 2, the coefficient C2 (-25) is clipped to say $+Th_{clip}$ e.g. -6 at the decoder. If $C_i > +T_{clip}$, then C_i is set to $+T_{clip}$ (step S84).

$|T_{clip}| = 6$ is only an example and in practice may have other values set by experiment.

Such clipping may or may not be performed also at the embedder of Figure 2.

In the embedder shown in Figure 2 it is not performed. However, in another embodiment, the procedure of Figure 13 may be applied prior to step S1 in Figure 3B.

The clipping is performed only for the purpose of calculating the parameter α_i. The coefficients C_i to which α_j. P_i is added do not have clipped values.

<u>Limiting α'</u>

The value of α' may be limited to be within a present range determined by upper and lower bounds.

<u>Trial processing and decoding- Figure 6</u>

Referring to Figure 6, an unmarked spatial domain image I is applied to an embedder 60. An example of the embedder is shown in Figure 8. The embedder calculates

$$Ci'' = Ci + \alpha_{T,j} Ri \quad \text{for } i = (j-1)L + 1 \text{ to } jL \text{ for each of } j=1 \text{ to } J.$$

where: Ci is a wavelet transform coefficient of the image; Ri is a watermarking symbol formed by combining a PRSS of JxL bits Pi with watermark data Wj. Symbol Ri has a value + or - 1; $\alpha_{t,j}$ is a trial value of the scaling factor for UMID (or watermark) data bit Wj. In this example $\alpha_{t,j}$ is initialised to 1. Figure 7 shows an example of a subsystem, for producing Ri.

The embedder also includes an inverse transformer which produces a spatial domain watermarked image Iw.

The image Iw is processed by a processor 62 to produce a processed spatial domain image Ip. The processor 62 is chosen to process the image according to a

process which the watermarked image is likely to encounter in use, and/or a process which may be applied to the image to deliberately remove or damage the watermark. JPEG processing using DCT transforms is a process which is known to be potentially damaging to some watermarks.

A decoder 64, an example of which is shown in Figure 9, decodes the processed image Ip. The decoder may extract the watermark data Wj. The decoder produces correlation values

$Sip,j' = \Sigma Cip.Pi$ for $i = (j-1)L + 1$ to jL for each of $j=1$ to J.

where Cip are wavelet coefficients of the processed image Ip and the sum is calculated over a length L of a PRSS having JxL bits Pi.

A calculator 66 calculates a new value of αj based on the magnitude of Sip,j to produce new trial values of $\alpha_{t+n,j}$ which is used as a new value in the trial embedder 60. n is the number of iterations used to calculate a final value $\alpha_{t+n,j}$ which is applied to an embedder 69. $n = 0,1,2$. Several iterations may be used. Preferably the number of iterations is limited to a predetermined number, e.g. 4, because the process 62 may be non-linear (JPEG processing is non-linear) and it is then unlikely that the iterations will converge to steady values of $\alpha t,j$.

Examples of (a) the calculator 66 and (b) the embedder 69 are shown in Figures 10 and 8 respectively.

<u>Calculating Ri, Figure 7.</u>

A PRSS generator 71 produces a PRSS having JxL bits Pi. A UMID generator 72 produces a UMID having bits Wj. In a modulator 73, each bit Wj of the UMID modulates, and is thus spread over, an L bit sequence of the PRSS. A data converter 74 converts the binary values 1 and 0 at the output of the modulator to produce symbols Ri of value +1 and -1 respectively.

<u>Embedder 60 and 69,- Figure 8.</u>

The embedder of Figure 8 comprises a wavelet transformer 82 which produces the wavelet coefficients Ci and an inverse transformer 85. A multiplier 84 calculates $\alpha_{t+n,j}.Ri$. An adder 83 adds $\alpha_{t+n,j}.Ri$ to Ci to produce.

$Ci' = Ci + \alpha_{t+n,j}.Ri$ for $i = (j-1)L + 1$ to jL for each of $j=1$ to J.

Thus each coefficient Ci is modified by a value of α associated with that coefficient and by one symbol Ri.

Unlike the example of Figures 2 and 3, Ri is a symbol stream comprising the PRSS modulated by the data to be embedded, and α is an unsigned magnitude.

Decoder 64-Figure 9

The decoder has a wavelet transformer 91 which produces wavelet coefficients Cip from the processed image Ip. A synchroniser 92 operating in known manner shifts the phase of the PRSS produced by a PRSS generator 93 so that it is in phase with the PRSS in the image Ip. A data converter 94 converts the PRSS values Pi to +1 and -1. A correlator calculates a correlation value

$Sip,j = \Sigma Cip.Pi \quad i = (j-1)L + 1$ to jL for each of $j=1$ to J.

A decoder 96 determines the values of the data bits Wj from the sign of the correlation values Sip,j.

Calculating α-Figures 10A, 10B and 10C

Referring to Figure 10A, new values of $\alpha_{t+1,j}$ are calculated by adding an offset to a basic fixed value $\alpha_{t,j}$ in an adder 99. The offsets are produced by an offset generator 95. The generator responds to an offset control value produced by a processor 97. The processor controls the offset and thus the values of $\alpha_{t+1,j}$ in dependence on the correlation values Sip,j.

Figures 10B and 10C illustrate examples of the operation of the processor.

Referring to Figure 10B, the correlation values Sip,j are compared at step S30 with the corresponding symbols Wj. The correlation values Sip,j are positive and negative, a positive value indicates a symbol 1 and a negative value a symbol 0, (if the values Sip are unchanged by the processing in processor 62). If the signs of Sip,j correctly represent Wj then the magnitude of Sip,j is compared with an upper threshold Th. If $|Sip,j| > Th$ then the value of αj is reduced for the next iteration $\alpha_{t+1,j}$. If $|Sip,j|$ is not greater than the threshold αj either remains unchanged for the next iteration $\alpha_{t+1,j}$ or is used as the final value of $\alpha t,j$.

If the sign of Sip,j indicates the incorrect value for Wj, then αj is increased for the next iteration $\alpha_{t+1,j}$.

Referring to Figure 10C, at step S40 a value (Sip,j)/L is calculated from Sip,j. That is the average correlation value over L symbols. That value is used as $\alpha_{t+1,j}$ for the next iteration. Preferably $\alpha_{t+1,j}$ is compared with an upper threshold Th at step S42. If $\alpha_{t+1,j}$ exceeds Th, then $\alpha_{t+1,j}$ is reduced. Otherwise it is compared (S46) with a lower threshold TL. If $\alpha_{t+1,j}$ is less than TL, $\alpha_{t+1,j}$ is increased (S48) otherwise it is unchanged (S49).

Modifications.

Other transforms

Whilst the invention has been described by way of example with reference to Wavelet transforms, it may be used with other transforms for example DCT.

Other material

Whilst the invention has been described by way of example with reference to material comprising images, e.g. video material , it may be applied to other material, for example audio material and data material.

Other Watermark data.

Whilst the invention has been described by way of example with reference to UMIDs as the watermark data, it may be used with other data as the watermark.

Wavelets

Wavelets are well known and are described in for example "A Really Friendly Guide to Wavelets" by C Valens, 1999 and available at http://perso.wanadoo.fr/polyvalens/clemens/wavelets/wavelets.html.

Valens shows that the discrete wavelet transform can be implemented as an iterated filter bank as used in sub-band coding, with scaling of the image by a factor of 2 at each iteration.

Thus referring to Figure 12, a spatial domain image is applied to a set of high pass HP and low pass LP filters. At level 1, the first stage of filtering, the image is filtered horizontally and vertically and, in each direction, scaled down by a factor of 2. In level 2, the low pass image from level 1 is filtered and scaled in the same way as in level 1. The filtering and scaling may be repeated in subsequent levels 3 onwards.

The result is shown schematically in Figure 11. Figure 11 is a representation normal in the art. At level one the image is spatially filtered into four bands: the lower horizontal and vertical band, lH_1, lV_1; the upper horizontal band hH_1, lV_1; the upper vertical band lH_1, hV_1; and the upper horizontal and vertical band, hH_1, hV_1. At level 2, the lower horizontal and vertical band, lH_1, lV_1 is filtered and scaled into the lower horizontal and vertical band, lH_2, lV_2; the upper horizontal band hH_2, lV_2; the upper vertical band lH_2, hV_2; and the upper horizontal and vertical band, hH_2, hV_2. At level 3 (not shown in Figure 11), the lower horizontal and vertical band, lH_2, lV_2 is further filtered and scaled.

UMIDs

The UMID or Unique Material Identifier is described in SMPTE Journal March 2000. Referring to Figure 13, an extended UMID is shown. It comprises a first set of 32 bytes of basic UMID and a second set of 32 bytes of signature metadata.

The first set of 32 bytes is the basic UMID. The components are:

•A 12-byte Universal Label to identify this as a SMPTE UMID. It defines the type of material which the UMID identifies and also defines the methods by which the globally unique Material and locally unique Instance numbers are created.

•A 1-byte length value to define the length of the remaining part of the UMID.

•A 3-byte Instance number which is used to distinguish between different 'instances' of material with the same Material number.

•A 16-byte Material number which is used to identify each clip. Each Material number is the same for related instances of the same material.

The second set of 32 bytes of the signature metadata as a set of packed metadata items used to create an extended UMID. The extended UMID comprises the basic UMID followed immediately by signature metadata which comprises:

•An 8-byte time/date code identifying the time and date of the Content Unit creation.

•A 12-byte value which defines the spatial co-ordinates at the time of Content Unit creation.

•3 groups of 4-byte codes which register the country, organisation and user codes

Each component of the basic and extended UMIDs will now be defined in turn.

The 12-byte Universal Label

The first 12 bytes of the UMID provide identification of the UMID by the registered string value defined in table 1.

Byte No.	Description	Value (hex)
1	Object Identifier	06h
2	Label size	0Ch
3	Designation: ISO	2Bh
4	Designation: SMPTE	34h
5	Registry: Dictionaries	01h
6	Registry: Metadata Dictionaries	01h
7	Standard: Dictionary Number	01h
8	Version number	01h
9	Class: Identification and location	01h
10	Sub-class: Globally Unique Identifiers	01h
11	Type: UMID (Picture, Audio, Data, Group)	01, 02, 03, 04h
12	Type: Number creation method	XXh

Table 1: Specification of the UMID Universal Label

The hex values in table 1 may be changed: the values given are examples. Also the bytes 1-12 may have designations other than those shown by way of example in the table. Referring to the Table 1, in the example shown byte 4 indicates that bytes 5-12 relate to a data format agreed by SMPTE. Byte 5 indicates that bytes 6 to 10 relate to "dictionary" data. Byte 6 indicates that such data is "metadata" defined by bytes 7 to 10. Byte 7 indicates the part of the dictionary containing metadata defined by bytes 9 and 10. Byte 10 indicates the version of the dictionary. Byte 9 indicates the class of data and Byte 10 indicates a particular item in the class.

In the present embodiment bytes 1 to 10 have fixed preassigned values. Byte 11 is variable. Thus referring to Figure 14, and to Table 1 above, it will be noted that the bytes 1 to 10 of the label of the UMID are fixed. Therefore they may be replaced by a 1 byte 'Type' code T representing the bytes 1 to 10. The type code T is followed

by a length code L. That is followed by 2 bytes, one of which is byte 11 of Table 1 and the other of which is byte 12 of Table 1, an instance number (3 bytes) and a material number (16 bytes). Optionally, the material number may be followed by the signature metadata of the extended UMID and/or other metadata.

The UMID type (byte 11) has 4 separate values to identify each of 4 different data types as follows:

'01h' = UMID for Picture material

'02h' = UMID for Audio material

'03h' = UMID for Data material

'04h' = UMID for Group material (i.e. a combination of related essence).

The last (12th) byte of the 12 byte label identifies the methods by which the material and instance numbers are created. This byte is divided into top and bottom nibbles where the top nibble defines the method of Material number creation and the bottom nibble defines the method of Instance number creation.

Length

The Length is a 1-byte number with the value '13h' for basic UMIDs and '33h' for extended UMIDs.

Instance Number

The Instance number is a unique 3-byte number which is created by one of several means defined by the standard. It provides the link between a particular 'instance' of a clip and externally associated metadata. Without this instance number, all material could be linked to any instance of the material and its associated metadata.

The creation of a new clip requires the creation of a new Material number together with a zero Instance number. Therefore, a non-zero Instance number indicates that the associated clip is not the source material. An Instance number is primarily used to identify associated metadata related to any particular instance of a clip.

Material Number

The 16-byte Material number is a non-zero number created by one of several means identified in the standard. The number is dependent on a 6-byte registered port ID number, time and a random number generator.

Signature Metadata

Any component from the signature metadata may be null-filled where no meaningful value can be entered. Any null-filled component is wholly null-filled to clearly indicate a downstream decoder that the component is not valid.

The Time-Date Format

The date-time format is 8 bytes where the first 4 bytes are a UTC (Universal Time Code) based time component. The time is defined either by an AES3 32-bit audio sample clock or SMPTE 12M depending on the essence type.

The second 4 bytes define the date based on the Modified Julian Data (MJD) as defined in SMPTE 309M. This counts up to 999,999 days after midnight on the 17th November 1858 and allows dates to the year 4597.

The Spatial Co-ordinate Format

The spatial co-ordinate value consists of three components defined as follows:

•Altitude: 8 decimal numbers specifying up to 99,999,999 metres.

•Longitude: 8 decimal numbers specifying East/West 180.00000 degrees (5 decimal places active).

•Latitude: 8 decimal numbers specifying North/South 90.00000 degrees (5 decimal places active).

The Altitude value is expressed as a value in metres from the centre of the earth thus allowing altitudes below the sea level.

It should be noted that although spatial co-ordinates are static for most clips, this is not true for all cases. Material captured from a moving source such as a camera mounted on a vehicle may show changing spatial co-ordinate values.

Country Code

The Country code is an abbreviated 4-byte alpha-numeric string according to the set defined in ISO 3166. Countries which are not registered can obtain a registered alpha-numeric string from the SMPTE Registration Authority.

Organisation Code

The Organisation code is an abbreviated 4-byte alpha-numeric string registered with SMPTE. Organisation codes have meaning only in relation to their registered Country code so that Organisation codes can have the same value in different countries.

User Code

The User code is a 4-byte alpha-numeric string assigned locally by each organisation and is not globally registered. User codes are defined in relation to their registered Organisation and Country codes so that User codes may have the same value in different organisations and countries.

Although illustrative embodiments of the invention have been described in detail herein with reference to the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments, and that various changes and modifications can be effected therein by one skilled in the art without departing from the scope and spirit of the invention as defined by the appended claims.